MINISTRY OF FORESTS

ANALYSIS OF INVESTMENTS IN SILVICULTURE IN BRITISH COLUMBIA

Province of British Columbia
Ministry of Forests

ANALYSIS OF INVESTMENTS IN SILVICULTURE IN BRITISH COLUMBIA

Ministry of Forests
Silviculture Branch
31 Bastion Square
Victoria, B.C.

August, 1989

ACKNOWLEDGEMENTS

This internal report was produced for Silviculture Branch by Frank Barber and Steve Carr under the advice and direction of Silviculture Branch's Director and Section Managers. The intent of this report is to provide some interim direction for FRDA II negotiations until the complete FRDA evaluation (currently under contract) is complete.

Peter Ackhurst
Director
Silviculture Branch

TABLE OF CONTENTS

	Page
TITLE	i
ACKNOWLEDGEMENTS	ii
TABLE OF CONTENTS	iii
EXECUTIVE SUMMARY	1
INTRODUCTION	4
A. INDICATORS OF ECONOMIC BENEFIT	4
EMPLOYMENT:	
- Direct or short-term employment	4
- Indirect or long-term employment	5
GOVERNMENT REVENUE:	
- Direct Government Revenue	5
- Indirect Government Revenue	5
IMPACT ON ECONOMY	6
INTANGIBLE BENEFITS	6
B. INVESTMENT ANALYSIS	6
EVALUATION INDICES:	
- Net Present Value (NPV)	7
- Present Value of Discounted Revenue to Discounted Cost Ratio(PVR/C)	7
ASSUMPTIONS	7
RESULTS	8
DISCUSSION	13
C. APPLICATION TO FRDA	17
D. SENSITIVITY ANALYSIS	17
E. CURRENT RESEARCH DEALING WITH ANALYSIS OF SILVICULTURE INVESTMENTS	18
BIBLIOGRAPHY	19
APPENDIX 1 Incremental Silviculture Benefits From FRDA I	21
APPENDIX 2 Sensitivity Analysis	33
APPENDIX 3 Economics of Silviculture:	
- Other Research to date	47

Executive Summary

This economic analysis was produced internally by Silviculture Branch staff to assess the economic benefits of FRDA I to the Province of British Columbia. The analysis was carried out for aggregated good and medium western hemlock stands on the coast and aggregated good and medium lodgepole pine stands in the interior. The benefits derived from silvicultural treatments are based on the Allowable Cut Effect "ACE". ACE means that an immediate increase in today's Allowable Annual Cut (AAC) can be attributed to expected future increases in yield due to silvicultural operations. Alternatively, this increase in merchantable volume would be used to offset projected wood supply shortages.

Four economic indicators used in this report to examine the benefits and costs associated with incremental silviculture activities are: Gross Domestic Product (GDP), Total Government Revenue, Direct Government Revenue, and Employment.

Two economic indicators, GDP and Total Government Revenue, both realized revenue/cost ratios greater than 1.0 for investments in all of the incremental silviculture activities examined (a positive NPV signifying a monetary return on investment after all costs have been subtracted). These results are indicated by activity in Table 1 of this Summary. All treatments resulted in the Government receiving greater revenue from stumpage and other indirect revenue than actual silviculture expenditures for each dollar invested.

Direct Government Revenue realized revenue/cost ratios equal to or greater than 1.0 for all treatments except backlog reforestation and conifer release on the coast and in the interior.

The fourth indicator, Employment, demonstrated significant increases in both short and long-term employment, particularly long-term over the life of the investments for both the coast and interior of British Columbia.

Based on a 100 ha unit, the monetary benefits from these indicators were applied to silviculture activities in the existing Forest Resource Development Agreement (FRDA).

FRDA has had a positive impact on the economy of B.C. by generating an additional $1.204 billion in GDP (in present value terms using 4 % discount rate, net of costs) in the interior and $605.5 million on the coast. In addition it will support approximately 1,575 permanent annual jobs (supported by AAC increases, over currently projected levels) and will provide short term employment over the five year period for over 3,128 people (on a full-time equivalency (FTE) basis) in the interior. For the coast FRDA supported 215 permanent annual jobs and 733 short-term jobs over the five year period.

In terms of Total Government Revenue, the B.C. government would receive an increase of $219.5 million over and above the original provincial part of the

TABLE 1: Benefits from FRDA I (Revenue/Cost Ratios)

ACTIVITY	B.C. GDP		Total Govt. Rev.		Direct Rev.		Employment	
	Coast	Interior	Coast	Interior	Coast	Interior	Coast Long Term	Interior (person yrs/100 ha)
1. Backlog Reforestation	7.4	6.7	1.7	1.4	0.8	0.6	1.22	1.22
2. Conifer Release	8.2	10.3	1.8	2.0	0.9	0.9	0.17	0.17
3. Spacing (Natural)	29.5	20.6	6.5	4.1	3.2	1.8	0.12	0.12
4. Space/Fert.(Nat)	25.1	18.1	5.5	3.6	2.7	1.6	0.24	0.24
5. Space/Fert.(Plant)	22.0	28.5	4.8	5.7	2.4	2.5	0.24	0.24
6. Space/Fert/Prune(Nat)	15.1	11.3	3.3	2.2	1.7	1.0	0.24	0.24
7. Space/Fert/Prune(Plant)	15.3	15.5	3.4	3.1	1.7	1.4	0.24	0.24

cost shared investment of $150 million in FRDA. The overall return to B.C. from FRDA based on the Allowable Cut Effect was $1.50 for every $1.00 invested in silviculture to maintain and enhance our forest industry. The overall return to Canada is $1.73 for every $1.00 invested in our forest resource.

Appendix I contains the assumptions and details of the analysis of benefits from FRDA I.

Further research is continuing in the area of silviculture investment analysis. A series of fifteen projects and models currently available, or being developed will provide valuable information on the impacts of silviculture activities on:

- biological response — alleviate wood supply shortages;
- employment generation/stability;
- economic stability — local and provincial; and
- changes in timber values and products and subsequent impact on markets and market values.

INTRODUCTION

The purpose of this internal paper is twofold:

1. To examine the benefits and costs associated with investments in incremental silviculture activities based on the best information available.
   This is limited to those activities performed under FRDA.

2. To present a list of the projects and models currently available, or being developed, on the analysis of silviculture investments.

This paper outlines the indicators of economic benefit used in the Investment Analysis, summarizes the results of this analysis, and then applies those results to the existing FRDA. The results are based on the best Growth and Yield information presently available in B.C., the Pacific Northwest and other parts of the world.

A. INDICATORS OF ECONOMIC BENEFIT

The following indicators are used to examine the economic benefits attributable to Government investments in silviculture.

EMPLOYMENT

Increased employment due to silviculture activities can take two forms:

Direct or short-term employment

This is based on person-days required to undertake various silviculture activities. Conversion factors are used to estimate short-term employment. These factors, listed as follows, are based on Backlog Reforestation Intensive Forest Management (BRIFM) Working Group recommended factors for estimating the direct employment generated from carrying out the work under FRDA[1].

Treatment/Activities	Estimated Employment (mandays/ha unless otherwise specified)
Backlog Planting	2.0
Site Rehabilitation	0.5
Surveys	0.1
Brushing	2.0
Spacing	4.0
Fertilization	0.1
Conifer Release	2.5
Nurseries	1 manday per 1,000 trees

[1]Note: A FRDA contract is currently underway in an attempt to refine these numbers - see Item #4 Appendix 3.

Indirect or long-term employment

This consists of an estimate of permanent jobs created through processing the forest into forest products. This generates economic activity in forest industries as well as other sectors of the economy. Forestry Canada has estimated that the impact on long-term employment by unit volume of harvest is 2.6 jobs generated in British Columbia per 1000 m^3 harvested (Jacques, 1988).

GOVERNMENT REVENUE

There are two types of government derived revenue: direct government revenue (stumpage); and indirect government revenue (forest industry corporate and personal tax revenue). This investment analysis will examine the direct government revenue and the total government revenue (direct and indirect) generated from silviculture investments.

Direct government revenue

Direct Government Revenue values used in this report are those established by the Government as one year targets in the derivation of initial average stumpage rates under the comparative value pricing method. Direct Government revenue includes:

a) Annual rents
b) Royalties
c) Fees on exported logs
d) Logging taxes
e) Small Business Forest Enterprise Program revenue
f) Non-competitive stumpage (initial average rates)
g) Other Charges

Direct Government Revenue per m^3 of harvest is calculated to be $\$8.59/m^3$ in the interior and $\$10.59/m^3$ on the coast. Estimates of harvest volumes are based on 12 months to June 1987 (Deloitte *et al*, 1988).

Indirect government revenue

Indirect government revenue is based on a 1987 Price Waterhouse study (adjusted for 1987 dollars) examining 10 year average estimate (1975-1985) of provincial revenues from the forest industry. Indirect government revenue includes:

a) Corporate Income Tax
b) Corporation Capital Tax
c) Social Services Tax
d) Fuel Tax
e) Protection Tax
f) Property Tax (Prov. & Mun.)
g) Personnel Income Tax
h) Personal Social Services Tax

Indirect government revenue per m^3 of harvest is calculated to be $\$10.64/m^3$ for both coast and interior.

IMPACT ON ECONOMY

According to several papers, Gross Domestic Product (GDP) at factor cost is the best measure of the contribution of an industry to any particular economy at the Regional or National level (Jacques 1988, Dobie 1988). GDP at 'factor cost' is equivalent to True Value Added and is the difference between the value of gross output of an industry and the cost of intermediate inputs such as materials, supplies, fuel and electricity, and purchased service inputs, etc. GDP at factor cost represents salaries and wages, capital cost allowances, and taxes and profits. Any further reference to GDP in this study is at factor cost. Forestry Canada has estimated that the GDP, generated through timber processing, is $97 GDP generated in British Columbia per m^3 of harvest per year (Jacques, 1988).

INTANGIBLE BENEFITS

In addition to the above mentioned indicators of economic benefit there are several other gains from silviculture investment that are no less beneficial but are difficult to quantify in tangible economic terms. The most important of these is community stability. In B.C. there are approximately 144 communities that are completely dependent on forestry for their economic livelihood (White et al, 1986). Many of these communities are within Timber Supply Areas (TSA's) that project significant reductions in wood supply in the next 10-30 years. Investment in silviculture can fill in forest stand age class gaps, thereby offsetting such problems.

Silviculture can also be used to enhance wildlife habitats (over-winter range), recreational opportunities (hunting, hiking, etc.) and produces aesthetically pleasing forest stands which are important to maintain good public relations.

An increasing concern today is the pressure of modern industrialization on the environment. Intensively managed second growth stands are more efficient at recycling oxygen and filtering pollutants from the air than old growth stands — providing environmental stability to counter the greenhouse effect.

B. INVESTMENT ANALYSIS

The objective of the investment analysis is to provide decision-makers with a measure that will demonstrate whether monies spent in silviculture constitute a sound investment.

It is not intended that this analysis provide a meaningful comparison of the opportunity cost of investment in silviculture versus investment in other areas (i.e., it is not intended to demonstrate that Government funds are best spent in silviculture rather than other Government programs; that is beyond the scope of this paper).

EVALUATION INDICES

Several indices can be used to evaluate investments in silviculture. In this Investment Analysis two of the accepted indices are used:

Net Present Value (NPV)

This can be defined as the present value of cash inflows minus the present value of cash outflows.

Present Value of Discounted Revenue to Discounted Cost Ratio (PV R/C)

The PV R/C, or Dollar Return per Dollar Invested, is the ratio of the Present Value of Cash Inflows to the Present Value of Cash Outflows. Henceforth this will be described as a revenue/cost ratio.

ASSUMPTIONS

Various assumptions were made in this Silviculture Investment Analysis:

1. Volume responses in this analysis were based on merchantable yields from silviculturally treated stands compared to natural untreated stands.

2. The undertaking of silviculture activities generates an, "Allowable Cut Effect" (ACE). This means that an immediate increase in today's Allowable Annual Cut can be attributed to expected future increases in yield due to silviculture operations. The use of ACE in forest investment analysis is common practice in British Columbia and the Pacific Northwest. It must be realized, however, that ACE is not always realizable for all TSA's due to timber supply disparities. Furthermore, in many cases the objective is to postpone current harvest benefits to some future point to enable offsetting 'falldown' or age class related gaps in the harvest schedule.

3. Untreated Backlog NSR areas will not yield a significant merchantable volume over the projected time-frame of this Analysis.

4. Backlog reforestation includes surveys, site rehabilitation, nursery costs (including transport and cold storage of seedlings) planting and brushing. This analysis assumes that established plantations will receive adequate funding for plantation maintenance (brushing) to allow the crop to reach a free growing stage. A risk allowance of 10% for plantation failure has been incorporated into the analysis.

5. Only benefits that accrue to the B.C. provincial government are utilized in the analysis.

6. A 4% social discount rate is assumed. This is consistent with the recommendations made in a paper on the social discount rate of silviculture investment (Heaps 1989, Draft FRDA report). This paper

suggested a discount rate range of 3-5%, this range is incorporated into the sensitivity analysis section of this paper.

7. A 60 year rotation time-frame on the coast, 90 years in the interior.

8. Growth and yield assumptions as outlined in Appendix 1.

In order to conduct the Investment Analysis, it was necessary to estimate an aggregated good and medium site index for coast and interior stands. Based on the best available information it was estimated that aggregated good and medium sites (coastal western hemlock) on the coast had a site index of 33 m at BH50YRS; 20 m at BH50YRS in the interior (lodgepole pine).

BH50YRS is the reference age at breast height that is used to measure a site's productivity using top height.

Incremental silviculture may provide an increase in merchantable volume to natural and planted stands, depending on the nature of the treatment. Volume multipliers have been estimated for the incremental silviculture treatments of conifer release, spacing, fertilization, and spacing plus fertilization (see Appendix 1).

RESULTS

Tables 1(a), 1(c) show the calculated NPV and revenue/cost ratios (PV of R/C) for the four indicators of economic benefit: GDP and Total Government Revenue (both direct and indirect), Direct Government Revenue and employment for both coastal and interior aggregated good and medium site stands.

Tables 1(b), 1(d) summarize the $ Benefits/ha/yr by activity.

A revenue/cost ratio greater than one indicates that the present value of cash inflows (revenue) is greater than the present value of cash outflow. In terms of GDP, silviculture investment demonstrates a very favourable return with the NPV of GDP at 4 % discount rate on the coast varying from approximately $433,350 to $1,918,520 per 100 ha treated and revenue/cost ratios varying from 7.4 to 29.5. In the interior at a discount rate of 4% the NPV of GDP ranged from $360,350 to $1,895,700 per 100 ha treated (all treatments) and revenue/cost ratios varying from 6.7 to 28.5.

The monetary benefits are based on a 100 ha basis and the life of the stand from the time of treatment to harvest. Annual benefits per ha (if assumed equal per year) must be calculated by dividing 100 (per hectare rather than 100 ha) then divide by the number of years from treatment to rotation.

Total revenue returns (direct and indirect) to the government from silviculture investments were also favourable. All treatments resulted in the government receiving greater revenue from stumpage and other indirect revenue than actual silviculture expenditures for each dollar invested. The revenue/cost ratios ranged from 1.4 to 6.5 on the coast and from 1.4 to 5.7 for the interior at a 4 % discount rate.

Table 1a: INVESTMENT ANALYSIS OF SILVICULTURE TREATMENTS:
AVERAGE B.C. CONDITIONS (PER 100 HA OF TREATMENT)
INTERIOR: LODGEPOLE PINE (22.5+ CM UTILIZATON)

TREATMENT	IMPACT ON THE ECONOMY		TOTAL B.C. GOV'T REVENUE		DIRECT GOV'T REVENUE		EMPLOYMENT	
	NPV OF GDP ($ 000's)	R/C RATIO	NPV OF TGR ($000's)	R/C RATIO	NPV OF DGR ($000's)	R/C RATIO	SHORT TERM PERSON YEARS (FTE BASIS)	LONG TERM PERM ANNUAL FOR IND JOBS
SITE INDEX = 20 m @ BH50YRS[1] 0.04%[2]								
1) BACKLOG REFORESTATION	651.9	6.7	44.1	1.4	(46.0)	9.6	2.10	1.22
2) CONIFER RELEASE (NAT)	360.4	10.3	40.2	2.0	(3.6)	0.9	1.04	0.17
3) SPACING (NAT)	1212.6	20.6	190.8	4.1	51.0	1.8	1.67	0.12
4) SPACING/FERT (NAT)	1347.7	18.1	204.0	3.6	47.5	1.6	1.71	0.24
5) SPACING/FERT (PLANT)	1895.7	28.5	320.6	5.7	105.1	2.5	1.71	0.24
6) SPACE/FERT/PRUNE (NAT)	1299.9	11.3	156.2	2.2	(0.3)	1.0	3.38	0.24
7) SPACE/FERT/PRUNE (PLANT)	1837.9	15.5	262.8	3.1	47.3	1.4	3.38	0.24

[1] Site index - aggregated good and medium lodgepole pine sites in the interior (Goudie, 1984).

[2] Discount rate of 4% as recommended by Dr. Terry Heaps, Dept. of Economics, Simon Fraser University; contracted paper on "FRDA - Social discount rate for Silviculture investments."

Note: Analysis deals with returns to B.C. provincial economy only, multiplier effects would produce additional revenues at the national level (Canada wide).

( ) indicates negative value

Table 1b: INVESTMENT ANALYSIS OF SILVICULTURE TREATMENTS:
AVERAGE B.C. CONDITIONS ($ BENEFITS/HA/YR BY ACTIVITY)
INTERIOR: LODGEPOLE PINE (22.5+ CM UTILIZATON)

TREATMENT SITE INDEX = 20 m @ BH50YRS[1] 0.04%[2]	IMPACT ON THE ECONOMY NPV OF GDP $ BENEFITS/HA/YR	TOTAL B.C. GOV'T REVENUE NPV OF TGR $ BENEFITS/HA/YR	DIRECT GOV'T REVENUE NPV OF DGR $ BENEFITS/HA/YR
1) BACKLOG REFORESTATION	72.4	4.9	(5.1)
2) CONIFER RELEASE	51.5	5.7	(0.5)
3) SPACING (NAT)	161.7	25.4	6.8
4) SPACING/FERT (NAT)	179.7	27.2	6.3
5) SPACING/FERT (PLANT)	252.8	42.8	14.0
6) SPACE/FERT/PRUNE (NAT)	173.3	20.8	0.04
7) SPACE/FERT/PRUNE (PLANT)	245.1	35.0	6.3

[1] Site index - aggregated good and medium lodgepole pine sites in the interior (Goudie, 1984).

[2] Discount rate of 4% as recommended by Dr. Terry Heaps, Dept. of Economics, Simon Fraser University; contracted paper on "FRDA - Social discount rate for Silviculture investments."

Note: Analysis deals with returns to B.C. provincial economy only, multiplier effects would produce additional revenues at the national level (Canada wide).

( ) indicates negative value

Table 1c: INVESTMENT ANALYSIS OF SILVICULTURE TREATMENTS:
AVERAGE B.C. CONDITIONS (PER 100 HA OF TREATMENT)
COAST: WESTERN HEMLOCK (32.5+ CM UTILIZATON)

TREATMENT	IMPACT ON THE ECONOMY		TOTAL B.C. GOV'T REVENUE		DIRECT GOV'T REVENUE		EMPLOYMENT	
	NPV OF GDP ($ 000's)	R/C RATIO	NPV ($000's)	R/C RATIO	NPV ($000's)	R/C RATIO	SHORT TERM PERSON YEARS (FTE BASIS)	LONG TERM PERM ANNUAL FOR IND JOBS
SITE INDEX = 33 m @ BH50YRS[1] 0.04%[2]								
1) BACKLOG REFORESTATION	786.2	7.4	84.0	1.7	(23.7)	0.8	2.1	1.22
2) CONIFER RELEASE	433.4	8.2	48.0	1.8	(6.1)	0.9	1.04	0.17
3) SPACING (NAT)	1766.1	29.5	338.2	6.5	137.7	3.2	1.67	0.12
4) SPACING/FERT (NAT)	1901.2	25.1	354.6	5.5	137.4	2.7	1.71	0.24
5) SPACING/FERT (PLANT)	1918.5	22.0	348.4	4.8	127.9	2.4	1.71	0.24
6) SPACE/FERT/PRUNE (NAT)	1849.1	15.1	302.4	3.3	85.2	1.7	3.38	0.24
7) SPACE/FERT/PRUNE (PLANT)	1879.1	15.3	309.0	3.4	88.5	1.7	3.38	0.24

[1] Site index - aggregated good and medium lodgepole pine sites in the interior (Goudie, 1984).

[2] Discount rate of 4% as recommended by Dr. Terry Heaps, Dept. of Economics, Simon Fraser University; contracted paper on "FRDA - Social discount rate for Silviculture investments."

Note: Analysis deals with returns to B.C. provincial economy only, multiplier effects would produce additional revenues at the national level (Canada wide).

( ) indicates negative value

Table 1d: INVESTMENT ANALYSIS OF SILVICULTURE TREATMENTS:
AVERAGE B.C. CONDITIONS ($ BENEFITS/HA/YR BY ACTIVITY)
COAST: WESTERN HEMLOCK (32.5+ CM UTILIZATON)

TREATMENT SITE INDEX = 20 m @ BH50YRS[1] 0.04%[2]	IMPACT ON THE ECONOMY NPV OF GDP $ BENEFITS/HA/YR	TOTAL B.C. GOV'T REVENUE NPV OF TGR $ BENEFITS/HA/YR	DIRECT GOV'T REVENUE NPV OF DGR $ BENEFITS/HA/YR
1) BACKLOG REFORESTATION	131.0	14.0	3.95
2) CONIFER RELEASE	108.4	12.0	(1.5)
3) SPACING (NAT)	392.5	75.2	30.6
4) SPACING/FERT (NAT)	422.5	78.8	30.5
5) SPACING/FERT (PLANT)	426.3	77.4	28.4
6) SPACE/FERT/PRUNE (NAT)	410.9	67.2	18.9
7) SPACE/FERT/PRUNE (PLANT)	417.6	68.7	19.7

[1] Site index - aggregated good and medium lodgepole pine sites in the interior (Goudie, 1984).

[2] Discount rate of 4% as recommended by Dr. Terry Heaps, Dept. of Economics, Simon Fraser University; contracted paper on "FRDA - Social discount rate for Silviculture investments."

Note: Analysis deals with returns to B.C. provincial economy only, multiplier effects would produce additional revenues at the national level (Canada wide).

( ) indicates negative value

Investment in backlog reforestation and conifer release on the coast and in the interior in natural stands all realized direct government revenue/cost ratios less than 1.0. All other silvicultural investments on the coast and in the interior for direct government revenue had revenue/cost ratios greater than 1.0.

In terms of employment, backlog reforestation will support the greatest number of permanent jobs (per 100 ha brought back into production) whereas spacing, pruning and fertilization activities yield the greatest short-term employment.

Tables 2(a),(b) relate the benefits from silvicultural activities to FRDA I. For Direct Revenue, only backlog reforestation and conifer release on the coast and in the interior had revenue/cost ratios less than 1.0.

DISCUSSION

The following points are included for discussion:

1. In various published economic analyses a 1-3% real increase in log prices per annum over time is generally assumed. No increase was assumed in this analysis as the legitimacy of applying a similar percentage increase to stumpage (to reflect a real increase in value per annum over time) is questionable.

2. The benefits derived in this analysis are B.C. Government benefits only. The National GDP was factored down from $130 to $97 per cubic metre to exclude benefits outside B.C. These figures were extracted from Jacques (1988) for publication.

3. The employment figures in this analysis are based on "Full Time Equivalency" (FTE's). As silviculture activities last 2-3 months substantially more people are employed than indicated in the "Short Term Employment" column of Tables 1 and 2.

4. Added value from incremental silviculture activities can be realized in three forms: (1) the substantial reduction in stump to mill handling costs; (2) reduced cost of processing fewer larger logs; and (3) the value increase from greater product diversity and larger lumber end product.

   Added value is discussed in more detail in Appendix 1 but is not included in this analysis for several reasons. First, added value cannot be equated to an increase in merchantable volume resulting from incremental silviculture activities. Therefore, the allowable cut effect (ACE) cannot be utilized to justify an increase in volume cut today. Second, added value may only be realized at harvest (end of rotation). Since these cost savings and increased product values are discounted over the 60 and 90 years of this analysis, the analysis was not sensitive to added value. Third, in the comparative value stumpage appraisal system it is not clear at this time how stumpage is affected by added product value.

Table 2a: BENEFITS FROM FRDA I
INTERIOR: LODGEPOLE PINE (22.5+ CM UTILIZATION)

TREATMENT	IMPACT ON THE ECONOMY FRDA I		TOTAL GOV'T REVENUE	DIRECT GOV'T REVENUE	EMPLOYMENT	
					SHORT TERM	LONG TERM
SITE INDEX = 20 m @ BH50YRS[1] 0.04%[2]	HA TREATED	NPV OF GDP ($ MILLIONS)	NPV OF TGR ($ MILLIONS)	NPV OF DGR ($ MILLIONS)	PERSON YRS (FTE BASIS)	PERM ANNUAL FOR IND JOBS
1) BACKLOG REFORESTATION	123,086	802.44	54.28	(56.58)	2,585	1,502
2) CONIFER RELEASE	4,837	17.43	1.95	(0.173)	50	8
3) SPACING	3,654	44.31	6.97	1.86	61	4
4) SPACING & FERTILIZATION	25,237	340.12	51.48	11.99	432	61
TOTAL		1,204.30	114.68	(42.90)	3,128	1,575

1 Site index - aggregated good and medium lodgepole pine sites in the interior (Goudie, 1984).

2 Discount rate of 4% as recommended by Dr. Terry Heaps, Dept. of Economics, Simon Fraser University; contracted paper on "FRDA - Social discount rate for Silviculture investments."

Note: Analysis deals with returns B.C. provincial economy only, multiplier effects would produce additional revenues at the national level (Canada wide)

( ) indicates negative value

Table 2b: BENEFITS FROM FRDA I
COAST: WESTERN HEMLOCK (32.5+ CM UTILIZATION)

TREATMENT	IMPACT ON THE ECONOMY FRDA I		TOTAL GOV'T REVENUE	DIRECT GOV'T REVENUE	EMPLOYMENT	
					SHORT TERM	LONG TERM
SITE INDEX = 33 m @ BH50YRS[1] 0.04%[2]	HA TREATED	NPV OF GDP ($ MILLIONS)	NPV OF TGR ($ MILLIONS)	NPV OF DGR ($ MILLIONS)	PERSON YRS (FTE BASIS)	PERM ANNUAL FOR IND JOBS
1) BACKLOG REFORESTATION	12,469	98.03	10.48	(2.95)	262	152
2) CONIFER RELEASE	1,907	8.26	0.91	(0.12)	20	3
3) SPACING	3,351	59.18	11.33	4.61	56	4
4) SPACING & FERTILIZATION	23,143	440.00	82.06	31.79	396	56
TOTAL		605.47	104.78	33.33	733	215

1 Site index - aggregated good and medium lodgepole pine sites in the interior (Goudie, 1984).

2 Discount rate of 4% as recommended by Dr. Terry Heaps, Dept. of Economics, Simon Fraser University; contracted paper on "FRDA - Social discount rate for Silviculture investments."

Note: Analysis deals with returns B.C. provincial economy only, multiplier effects would produce additional revenues at the national level (Canada wide)

( ) indicates negative value

5. Unlike fertilization, spacing is very labour intensive. Even on the basis of the economic indicator "Direct Government Revenue" (Tables 1(a&b) spacing pays. Spacing plus fertilization and pruning in natural stands in the interior using this same indicator also pays. Looking at the other two economic indicators "Total Government Revenue" and "Gross Domestic Product" spacing not only employs a large labour force but provides a substantial return to the economy of B.C.

The cost of creating and training a spacing labour force is high. One of the main reasons spacing (using "Direct Government Revenue") had a low NPV revenue/ cost ratio of 1.8 in the interior was the fact that the cost per hectare spacing figure used in the analysis was from the MOF Annual Report (1987). This is an accepted, published figure that is artificially high for several reasons:

(1) Spacing costs vary with species, terrain, stems removed per hectare, access, travel time, and many other factors;
(2) Most of the spacing to date has been done by job creation crews where substantial training is required with high rates of employee turnover;
(3) Spacing has mostly taken place in stands that are carrying far too many stems per hectare. The cost of spacing is directly proportional to the number of stems to be removed per hectare. Spacing costs in planted second growth stands will be significantly reduced as far fewer trees will be removed per hectare. The revenue/cost ratios for all three economic indicators are low in the spaced planted stands as costs of spacing a natural and a planted stand were assumed to be the same. In reality this is not true. Spacing planted stands (if deemed necessary from excessive ingrowth) will cost less than spacing natural stands; and
(4) The average spacing cost used over the entire province was separated out for coastal and interior based on hectares treated and regional cost averages. Therefore, with lower and more realistic spacing costs, the low NPV's for spacing and spacing plus fertilization (using the indicator "Stumpage" or "Direct" Revenue) may still be low but greater than the tables now indicate. The fact is that spacing costs are barely recovered through stumpage alone on a pure investment basis. When considering the economic/social effects of spacing, however, spacing and spacing plus fertilization provides a significant return on investment.

When pruning is added to spacing plus fertilization the NPV becomes even lower, particularly in natural stands in the interior. Pruning, like spacing, is very labour intensive. Unlike spacing, however, pruning does not increase merchantable volume, therefore, no allowable cut effect. Pruning does increase wood value but this added value was not included in this analysis. Again, pruning provides employment. When the employment requirements of pruning are included by using the other two economic indicators (GDP and Total

Government Revenue) pruning, coupled with spacing plus fertilization, provides a healthy return to the economy of B.C.

For this analysis the numbers used to generate NPV's for the three economic indicators are realistic and conservative. Greater benefits would be derived from incremental silviculture activities if "added value" were included in the analysis. Also, the entire analysis is based on the effect of increased merchantable volume resulting from incremental silviculture activities and the assumption that the allowable cut effect is real, based on the existing inventory of mature timber remaining in the province today.

C. APPLICATION TO FRDA

Tables 2(a),(b) summarize the estimated and projected benefits from FRDA using the Investment Analysis data generated in the previous section.

FRDA silviculture activities have had a positive impact on the B.C. economy by generating an additional $1.204 billion in GDP (12.4 million cubic metres of commercial timber) in the interior and $605.5 million (6.2 million cubic metres) on the coast. In addition it will support approximately 1,575 permanent jobs (supported by AAC increases, over currently projected levels) and will provide short term employment over the five year period for over 3,128 people (on a full-time equivalency (FTE) basis) in the interior. For the coast FRDA supported 215 permanent annual jobs and 733 short-term jobs over the five year period.

In terms of total government revenue, the B.C. government would receive an increase of $219.5 million over and above the original provincial part of the cost shared investment of $150 million in FRDA. The overall return from FRDA based on the Allowable Cut Effect was $1.50 for every $1.00 invested in silviculture to maintain and/or enhance our forest industry.

These are conservative estimates since the entire average unit cost of each incremental silviculture activity was used in the analysis. Under FRDA the B.C. government actually only pays for half of these costs since operational activities under FRDA are cost-shared with the federal government.

D. SENSITIVITY ANALYSIS

Sensitivity analysis is a useful tool in tackling problems created by the existence of uncertainty pertaining to particular parameters incorporated into an investment analysis. The two parameters of concern in this analysis are the social discount rate and the range of site indices for stands for aggregated good and medium sites.

Appendix 2 contains a detailed sensitivity analysis for the above mentioned parameters.

It is evident from the analysis that Backlog reforestation is more sensitive to site productivity and, to a lesser extent, discount rates. GDP was the most sensitive of the economic indicators to discount rates and site productivity (demonstrates the largest variation). For GDP, revenue/cost ratios varied from 1.7 with a lower site index - high discount rate, to 12.6 for a higher site index -low discount rate combination.

Tables 2-1(1-3) and 2-2(1-3) represent a matrix of present value revenue/cost ratios for GDP, total government revenue and direct government revenue for a range of discount rates (3-5%) and site indices ranging from 15-22 m in the interior and 25-35 m on the coast. In terms of revenue/cost ratios the impact of silviculture investment on B.C.'s GDP and total revenue remains greater than one over the entire range of parameter values.

Tables 2-1(1-6), demonstrate a pattern for backlog reforestation and conifer release different from the other incremental activities. As site productivity increased the R/C ratios for all economic indicators increased accordingly. With the other incremental activities, however, with increasing site productivity the R/C ratios increased and peaked at an approximate site index of 20 m at BH50YRS.

For Tables 2-2(1-6), for all silvicultural treatments on the coast the R/C ratios for all economic indicators increased or increased and levelled off with increasing site productivity.

For coast and interior the revenue/cost ratios for all three economic indicators for all silvicultural treatments decreased as discount rates increased from 3 - 5 %.

E. CURRENT RESEARCH DEALING WITH ANALYSIS OF SILVICULTURE INVESTMENTS

The following list summarizes current projects and models currently available, or being developed, on the analysis of silviculture investments.
A description of each project or model is included in Appendix 3.

1. Economics of Silviculture
2. Articulation of Preferences Over Objectives for Evaluating Silvicultural Investment Options
3. FRDA - Biological Response to Silvicultural Treatments
4. FRDA - Employment Generation
5. FRDA - Delivered Wood Costs
6. FRDA - Overall Evaluation
7. FRDA - An Analysis of Changes in timber values due to silviculture treatments under the Canada-British Columbia FRDA
8. FRDA - The Social Discount Rate for Silvicultural Investments
9. FORCYTE - 11
10. Forest Level Silviculture Impact Analysis: Joint Project
11. Silviculture Decision Support System (SDSS)
12. Douglas-fir Task Force
13. Lodgepole Pine Task Force
14. Economic Impact Monitoring Program
15. Company Specific Analysis

BIBLIOGRAPHY

1. Baumgartner, D., et al. 1985. Lodgepole Pine - The Species and its Management. Symposium Proceedings, 381 pp.

2. Deloitte, Haskins and Sells. March 1988. Review of the Stumpage Computation Process using the Comparative Value Pricing Method. 39 pp.

3. Dobie, James. 1988. Some Economic Aggregates for Canadian Forest Industry. For. Chron 64 355-359.

4. Fight, R.D. and D.G. Briggs. 1986. Importance of Tree Size and Volumes Removed in Silvicultural Decisions - Douglas-fir: Stand Management for the Future. College of Forest Resources, Univ. of Washington. Contrib. No. 55: (317-322).

5. Goudie, J. 1984. Interim Managed Stand Yield Tables for Lodgepole Pine. B.C.F.S. Res. Br. Unpublished Report.

6. Haley, David. 1972. Western Stand Management Committee Meeting Proceedings. 161 pp.

7. Heaps, T. 1989. FRDA - Social discount rate for Silviculture investments. Dept. of Economics, Simon Fraser Univ. (FRDA draft).

8. Jacques, Romain. 1988. Impact of Forestry Activity on the Economy of Canada and its Provinces. Information report E-X-39. Economics Branch. Canadian Forest Service.

9. Kellogg, R.M. 1988. Second Growth Douglas-fir: Its Management and Conversion for Value. A Report on the Douglas-fir Task Report. Draft Working Copy.

10. McMullan, D. and R. Monchak. 1989. Personal communication.

11. Ministry of Forests. 1987. Ministry of Forests 1987 Annual Report. B.C.F.S. Publication.

12. Mitchell, K. and I. Cameron. 1985. Managed Stand Yield Tables for Coastal Douglas-Fir: Initial Density and Precommercial Thinning. Lw Rep. No. 31, 69 pp.

13. Reed, F.L.C. 1988. The Potential Economic Impact of Biotechnology on the Forest Sector. NSERC/Industry Research Report, 22 p.

14. Smith, Stephen. 1987. Impact of Intensive Forestry Practices on Net Stand Values in British Columbia. Nawitka Resource Consultants, 78 p.

15. Sterling Wood Group Inc. 1988. **Analysis of changes in Timber Values due to Silviculture Treatments under the Canada-British Columbia Forest Resource Development Agreement.** FRDA Report 041, 67 p.

16. Thomson, T.M. & Assoc. Ltd. 1987. **Silviculture Program Review: Study 4-1 Intensive Silviculture.** 106 p. Unpublished Report.

17. White, W. et al. 1986. **Forest Sector Dependence in Rural British Columbia 1971-1981.** Information Report BC-X-178. Pacific Forestry Centre, Canadian Forestry Service.

APPENDIX 1

INCREMENTAL SILVICULTURE BENEFITS FROM FRDA I

INCREMENTAL SILVICULTURE BENEFITS FROM FRDA I

The investment analysis to determine the benefits from FRDA I was conducted for the coast — aggregated good and medium coastal western hemlock sites (assumed to be 33.0 m @ BH50YRS), and for the interior — aggregated good and medium lodgepole pine sites (assumed to be 20.0 m @ BH50YRS). The range of site indices used in this analysis adequately covers the range of what the real aggregated good and medium sites are for the coast and interior.

"Managed Stand Yield Tables for coastal Douglas-fir: Initial Density and Precommercial Thinning" (Mitchell and Cameron, 1985) were used for yield projections for various coastal western hemlock stands ranging from site index 25 m to 35 m site height at BH50YRS. Coastal western hemlock was assumed to be the species most representative of coastal species. Yields in coastal western hemlock stands are comparable to yields in coastal Douglas-fir stands of the same site index, however, the number of stems per hectare may be higher in hemlock stands. This would impact directly on average stand diameters.

"Managed Stand Yield Tables for interior Lodgepole pine: Initial and post-spacing Density" (Goudie, 1984) were used for yield projections for various lodgepole pine stands ranging from site index 15 m to 22 m site height at BH50YRS.

The highest utilization standards were used in this analysis to most clearly demonstrate the effect of spacing in natural and planted stands, and to promote the concept of fewer larger stems per hectare (switching from maximizing biological productivity — biomass, to optimizing economic benefits from processing fewer larger trees of higher value). British Columbia's forest industry is undergoing a transition from old-growth natural stands to producing high quality, higher valued second-growth stands — a tradeoff between maximizing total volume from many small diameter stems to the added value from fewer larger stems harvested in a shorter rotation.

A merchantable volume utilization level of 32.5+ cm (12.8+ inches) with a 0.30 m stump height and 10 cm (4 inch) top was used for western hemlock on the coast. For lodgepole pine in the interior a merchantable volume utilization level of 22.5+ cm (8.9+ inches), 0.30 m stump height and a 10 cm diameter top was used.

The base rotation age for all stands on the coast was assumed to be 60 years, with a 90 year rotation in the interior. Coastal densities at rotation (60 years) were targeted at 500 sph, while interior Pl stands were targeted at 750-900 sph. Natural stands, on the coast were assumed to regenerate to 4440 sph. For the interior, natural stands were assumed to regenerate to 8260 sph. Planting densities on the coast averaged 995 sph (MOF Annual Report, 1987), while interior planting densities averaged 1195 sph.

Costs for silviculture activities are outlined in Table 1-1 for the coast and interior based on MOF Annual Report figures (1988).

TABLE 1-1: SILVICULTURE ACTIVITY COSTS FOR COAST AND INTERIOR

TREATMENTS	SILVICULTURE COSTS Interior	Coast
1. Spacing	$547	$783
2. Fertilization	$169	$169
3. Pruning (2 m)	$330[1]	$225[2]
4. Pruning (4 m)	$330[1]	$225[2]
5. Conifer Release	$405	$624
6. Planting	$403[3]	$408[4]
7. Rehabilitation	$253	$296
8. Seedling Cost	$0.186/tree	$0.185/tree
9. Brushing (manual)	$497	$484
10. Brushing (chemical)	$242	$376
11. Avg. Brush (man + chem)	$306	$403
12. Surveys	$9	$13.4

[1] Based on 1110 sph
[2] Based on 500 sph
[3] Based on 1265 sph
[4] Based on 995 sph

For backlog reforestation it was assumed that 10% of all areas rehabilitated on the coast and interior would fail — these sites are retreated and are accounted for in the investment analysis. It is also assumed that a backlog NSR stand has no harvestable volume at rotation.

Mean annual increments (MAI's) for backlog reforestation and conifer release were taken from "Maximum mean annual increment" tables of Mitchell and Cameron (1985) and Goudie (1984) Managed Stand Yield Tables. Conifer release was carried out at age 20 years. The released stands were assumed to grow at 70% of full stocking (70% of MAI of a stand with the same post-spacing density) for a 20 year response period. After 20 years it was assumed that the unreleased stands were putting on 70% of the volume per year of the released stand (49% of MAI of a stand with the same post-spacing density). The incremental difference was 21%.

Incremental silviculture activities provide a volume plus added value effect to naturally regenerated second-growth stands. For second-growth planted stands, this may or may not be true. Fertilization in a planted stand will increase merchantable volume at the end of a fixed rotation period, but spacing may reduce final merchantable volume. If too many stems are removed and/or not enough time is allowed for the remaining stems to recover the merchantable volume lost from spacing, then spacing will reduce final merchantable yield.

Spacing may increase final merchantable volume where too many stems have been planted per hectare or natural fill-in (ingrowth) has resulted in an overstocked stand. Spacing such stands early enough will control stocking (density and distribution) through the removal of excess stems that as yet have no accumulated merchantable volume.

Volume response from incremental silviculture activities in natural and planted stands can be equated directly to the allowable cut effect (ACE). This means that, given an inventory of old-growth, the volumes gained through incremental silviculture may be realized now instead of waiting until rotation. Old-growth reserve volumes may be drawn down today reflecting the increase in volume production on second-growth treated natural and planted stands.

Alternately, added value is not directly related to volume response and cannot be equated to the allowable cut effect. Added value can only be realized at the time of harvest through increased wood quality, reduced harvest, transport, sorting and milling costs and an increase in end product diversity from larger piece sizes.

Added value from incremental silviculture activities will be discussed in detail following the section entitled "Volume Response."

1. Volume Response

For this analysis the volume responses from incremental silviculture activities were determined using a natural unspaced stand of 8260 sph from Goudie's (1984) report as a baseline for the interior and a natural unspaced stand of 4440 sph for the coast.

A. Interior: Planting and Spacing vs. Natural

Table 1-2 summarizes volumes of natural stands spaced to different residual densities. Merchantable volumes are based on a 22.5+ cm utilization. This level of utilization is a more realistic and product target for intensively managed second-growth stands.

TABLE 1-2: Natural Pl stands established at 8260 sph; no spacing; spacing to 1110 sph, and a planted Pl stand established at 1110 sph.

S. Index	Treatment	Merch. vol m^3/ha			Height
		12.5+ cm	17.5+ cm	22.5+ cm	
15 m @ 90 yrs	8260 sph	193	67	15	19.3 m
18 m @ 90 yrs	8260 sph	314	188	62	22.6 m
20 m @ 90 yrs	8260 sph	373	289	76	24.8 m
22 m @ 90 yrs	8260 sph	435	404	228	26.8 m
15 m @ 90 yrs	8260-1110	144	121	52	19.3 m
18 m @ 90 yrs	8260-1110	223	214	155	22.6 m
20 m @ 90 yrs	8260-1110	284	281	244	24.8 m
22 m @ 90 yrs	8260-1110	366	365	333	26.8 m
15 m @ 90 yrs	1110 sph	156	154	109	19.3 m
18 m @ 90 yrs	1110 sph	243	243	233	22.6 m
20 m @ 90 yrs	1110 sph	317	317	315	24.8 m
22 m @ 90 yrs	1110 sph	418	418	417	26.8 m

* Merchantable volumes in this table were interpolated from Goudie's (1984) (Managed Stand Yield Tables for Interior Lodgepole Pine: Initial and Post-Spacing Density." These volumes have been operationally scaled down to represent growth and yield on an emperical basis and not based on fully stocked permanent sample plots.

The merchantable volume (at 22.5+ cm) at 90 years for the aggregated good and medium site planted lodgepole pine in the interior is higher than an aggregated good and medium site natural stand for several reasons. First, the density and distribution of stems on a per hectare basis is determined at the time of planting in a managed stand. The density and distribution of stems in a natural stand can be compared to an irregular planted stand as determined in Mitchell's (1986) study. Mitchell found mortality in a uniformly square planted stand to be less than in a more irregular planted (0.9 m planting standard deviation) stand. Fewer surviving trees (at age 60 years) in the irregular planted stand accounted for 105 m^3/ha less total volume than the uniformly planted stand.

Secondly, in a planted stand significantly fewer stems are present per hectare, meaning that competition sets in at a later date, therefore, maximum tree growth for a longer period of time (open grown) prior to competition, and mortality is significantly less in a planted stand. Effectively, MAI in a planted stand is therefore putting on more merchantable volume and sooner than in a natural stand. If a natural stand is spaced early enough there should be little or no difference in total and merchantable volume and diameter growth with that of a planted stand.

From Table 1-2, however, there are two important points to discuss: firstly, there is still a significant difference between the natural-spaced and planted stand volumes at the 22.5+ cm utilization level. This may be due to controlling density and distribution (stocking) in the natural stand too late in the development of the stand and that some commercial volume was waste spaced. Secondly, it appears that on the better sites merchantable volume is higher in the unspaced stand than in the spaced stand. This may be explained in part by the increased productivity on higher sites and the ability of these sites to carry more stems to rotation. There is a tradeoff between the numbers of stems a site can carry and its productivity, but that is beyond the scope of this analysis.

Smith (1987) demonstrated that all stems in the spaced stand in his study became merchantable at 50 years of age. This was about 40 years before all the stems in the untreated stand (natural) became merchantable.

Thirdly, there is no regeneration delay in a planted stand. In a natural stand the regeneration delay may be 3-10 years or longer. Such a delay in stand growth will be directly reflected in lower merchantable volume.

Assumptions about planting and spacing in this analysis:
- spacing was carried out at age 15 years in natural stands;
- a natural stand spaced young enough would grow the same as a planted stand of same age;
- volume increase from spacing: equal to volume difference between natural unspaced and natural spaced lodgepole pine stands (Goudie, 1984);
- volume increase from planting: difference in volume of planted over natural untreated;
- 12 year harvest horizon over which ACE applied (due to harvest scheduling of increased areas to be cut; and
- volume increase per year from spacing was assumed constant (the total volume increase divided by 12).

B. Interior: Fertilization

From literature summarized in Baumgartner et al. (1985) lodgepole pine responds well to fertilization. Lack of growth response in fertilization research trials has been attributed to fertilization acting like a chemical spacing treatment — the response being increased mortality in overstocked stands. Based on Baumgartner's work it was assumed in this analysis that one application of urea fertilizer would result in a 1.67 m^3/ha/yr increase in MAI for a 12 year response period. The 20 m^3/ha increase in merchantable volume from fertilization can be equated to roughly a 6.6% increase in volume over the rotation of the aggregated good and medium site natural stand (20.0 m @ BH50YRS). For simplicity, the 20 m^3/ha response from one application of urea fertilizer was used across all sites for both interior and coastal stands.

Assumptions about fertilization in this analysis:
- fertilization was carried out at age 15 years in planted stands only — the volume response from fertilization added onto the yield from a planted stand;
- a 20 m^3/ha/yr volume increase at rotation (90 years);
- a 12 year response period over which ACE was applied (based on harvest scheduling to identify and harvest increased areas/ volumes); and
- the fertilization response value was assumed constant for each year and constant overall sites in this analysis.

Spacing Plus Fertilization

For the combination of spacing plus fertilization, the following assumptions were made:
- spacing and fertilization were both carried out at age 15 years;
- a 20 m^3/ha/yr volume increase at rotation (90 years);
- a 12 year volume growth response period over which ACE was applied; and
- the spacing plus fertilization response value was assumed constant for each year and constant overall sites.

Spacing Plus Pruning Plus Fertilization

The assumptions for spacing plus fertilization plus fertilization are the same for spacing plus fertilization except:
- 0% volume response due to pruning; in fact, there may be a slight reduction in total volume due to pruning live branches.

Conifer Release

The assumptions for conifer release were summarized in the introduction:
- conifer release is undertaken in natural stands at 20 years;
- 20 year volume growth response from conifer release at 70% MAI of a fully stocked natural stand; and
- after 20 years the untreated stand is growing at 70% MAI of the treated stand — a growth difference between conifer release and unreleased stands of 21% of the net MAI of the fully stocked natural stand. This difference is accumulative to age 90 years.

C. Coast: Planting and Spacing vs. Natural

Tables 1-3 (a, b) summarize volumes of natural stands spaced to different residual densities. Merchantable volumes are based on a 32.5+ cm utilization. This level of utilization is a more realistic end product target for intensively managed second-growth stands.

TABLE 1-3(a): Natural WH stands established at 4400 sph (no spacing) and planted WH stands established at various densities (2500-500)

Site Index	Height	Treatment	Merchantable Volume* 17.5+cm	22.5+cm	32.5+cm 1.0	32.5+cm 0.816
25 m @ 60 yrs	25.3 m	4440	228	123	0	0
30 m @ 60 yrs	30.4 m	4440	368	313	89	73
33 m @ 60 yrs	33.4 m	4440	456	418	209	171
35 m @ 60 yrs	35.4 m	4440	513	494	309	252
25 m @ 60 yrs	25.3 m	2500	228	114	6	5
30 m @ 60 yrs	30.4 m	2500	377	317	39	32
33 m @ 60 yrs	33.4 m	2500	468	432	152	124
35 m @ 60 yrs	35.4 m	2500	533	507	294	240
25 m @ 60 yrs	25.3 m	1110	269	181	8	7
30 m @ 60 yrs	30.4 m	1110	404	368	130	106
33 m @ 60 yrs	33.4 m	1110	501	478	267	218
35 m @ 60 yrs	35.4 m	1110	571	554	380	310
25 m @ 60 yrs	25.3 m	750	237	213	27	22
30 m @ 60 yrs	30.4 m	750	366	358	216	170
33 m @ 60 yrs	33.4 m	750	460	455	380	310
35 m @ 60 yrs	35.4 m	750	527	523	497	406
25 m @ 60 yrs	25.3 m	500	195	194	72	59
30 m @ 60 yrs	30.4 m	500	306	306	286	233
33 m @ 60 yrs	33.4 m	500	387	381	425	347
35 m @ 60 yrs	35.4 m	500	448	448	521	425

* Merchantable volumes in this table were interpolated from Mitchell and Cameron (1985), "Managed Stand Yield Tables for Coastal Douglas-fir: Initial Density and Precommercial Thinning." Unlike Table 1-2 the operational scaledown factor (0.816) for hemlock was available and has been included in Tables 1-3(a,b) for comparison at the 32.5+ cm utilization level.

The merchantable volume (at 32.5+ cm) at 60 years for the aggregated good and medium site planted western hemlock stand on the coast is higher than the aggregated natural stand for the same reasons as pointed out for the interior analysis.

TABLE 1-3(b): Spacing coastal western hemlock stands ranging from 4440 to 1110 to various post spacing densities (1110-500 sph)

Site Index	Height	Treatment	Merchantable Volume* 17.5+cm	22.5+cm	32.5+cm 1.0	32.5+cm 0.816
25 m @ 60 yrs	25.3 m	4440-1110	286	195	96	78
30 m @ 60 yrs	30.4 m	4440-1110	427	392	299	244
33 m @ 60 yrs	33.4 m	4440-1110	527	503	450	367
35 m @ 60 yrs	35.4 m	4440-1110	592	583	592	483
25 m @ 60 yrs	25.3 m	4440-500	238	232	96	79
30 m @ 60 yrs	30.4 m	4440-500	362	359	299	244
33 m @ 60 yrs	33.4 m	4440-500	455	455	450	368
35 m @ 60 yrs	35.4 m	4440-500	523	523	592	483
25 m @ 60 yrs	25.3 m	2500-1110	285	191	8	6
30 m @ 60 yrs	30.4 m	2500-1110	433	393	73	59
33 m @ 60 yrs	33.4 m	2500-1110	531	503	248	202
35 m @ 60 yrs	35.4 m	2500-1110	596	581	308	251
25 m @ 60 yrs	25.3 m	2500-500	240	277	62	51
30 m @ 60 yrs	30.4 m	2500-500	366	366	328	268
33 m @ 60 yrs	33.4 m	2500-500	461	461	506	413
35 m @ 60 yrs	35.4 m	2500-500	531	531	607	495
25 m @ 60 yrs	25.3 m	1110-500	219	215	65	53
30 m @ 60 yrs	30.4 m	1110-500	340	340	303	247
33 m @ 60 yrs	33.4 m	1110-500	430	430	454	370
35 m @ 60 yrs	35.4 m	1110-500	495	495	554	452

* Merchantable volumes in this table were interpolated from Mitchell and Cameron(1985), "Managed Stand Yield Tables for Coastal Douglas-fir: Initial Density and Precommercial Thinning." Again, the operational scaledown factor (0.816) has been included to represent empirical yields vs. yields from fully stocked permanent sample plots.

The merchantable volume (at 32.5+ cm) at 60 years for the aggregated good and medium site planted western hemlock stand on the coast is higher than the aggregated natural stand for the same reasons as pointed out for the interior analysis.

3. Added Value

Added value responses to incremental silviculture are not well documented in the literature. Added value results from an increase in stem piece size and/or an increase in wood quality resulting from incremental silviculture activities. Added value cannot, however, be equated to increased volume and therefore the allowable cut effect "ACE" cannot be used to justify an increase in volume cut now.

Added value can only be realized at harvest. Even at harvest, however, added value cannot be accurately accounted for in the the comparative value appraisal system. Also, due to the long discounting period involved in traditional investment analysis, investment analysis was not sensitive to added value realized at harvest (100 years).

(a) Piece size

Through incremental silviculture activities fewer larger pieces of higher wood quality can be grown to the same merchantable volume as an untreated stand but in a much shorter time-frame. Alternately, in the same time-frame, more merchantable higher quality wood can be grown on fewer stems per hectare.

Logs bought and sold in the coast log market are priced according to their species and grade. Top-end diameter is one of the chief parameters of the grading system and it is possible to trace the change in log price with changes in diameter criteria. Generally, price varies directly with diameter. The larger the top-end diameter the higher the price.

There are three values associated with larger piece size. First, more merchantable volume per piece equates to more volume extracted, hauled and sorted. If the same merchantable volume is extracted, hauled and sorted on half the number of stems an untreated stand would produce, this translates to a 25-40% reduction in handling costs (McMullan and Monchak, 1988). It is also evident that processing larger, more uniform and higher grade logs will be less costly for the sawmill which is cutting trees from these improved stands. The sum of these cost reductions will often exceed 25 percent (Reed, 1988). In a recent study for interior Douglas-fir Fight and Briggs (1986) noted that milling costs increased by as much as 65 percent when log diameter decreased from 30.5 cm to 15.2 cm.

Secondly, lumber recovery increases with increased piece size. Figure 1-1 (Coastal Douglas-fir Task Force--Forintek) illustrates an increase in lumber recovery up to 30 cm and then levels off.

Thirdly, higher value products can be processed from larger piece sizes. Table 1-4 from the Douglas-fir Task Force Report (Kellogg, 1988) demonstrates no significant increase in lumber product value from 2x4's up to 2x8's but a significant increase in lumber value for 2x10's. Figure 1-2 illustrates the increase in 2x10 outturn percent relative to increase in top diameter.

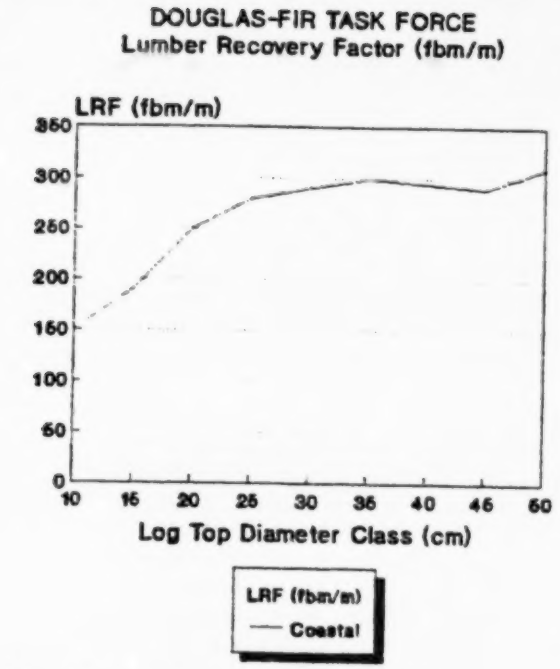

Figure 1-1: Lumber Recovery Factors for Mill-Run Logs

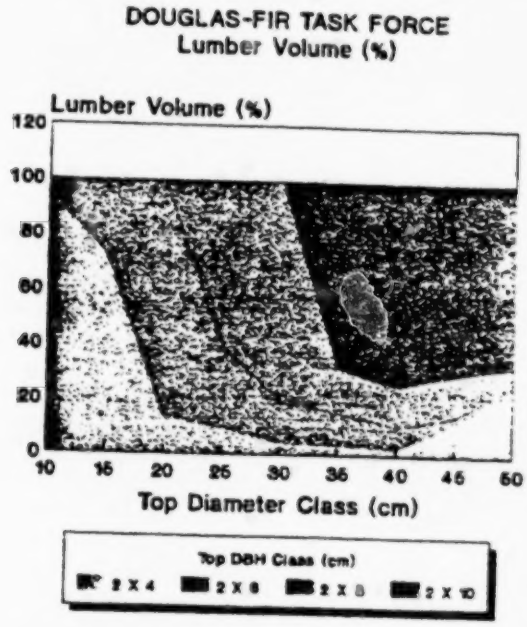

Figure 1-2: Lumber Dimension Yields to Mill-Run Log Size (area under each coloured curve)

Table 1-4: Lumber Prices

Dimension	Grade				
	Select	No. 1	No. 2	No. 3	Econ.
			($/MFBM)		
2 x 4	192	178	178	121	53
2 x 6	184	170	170	104	51
2 x 8	189	175	175	89	53
2 x 10	240	222	222	97	66

(b) Wood Quality

The enhancement of wood quality in second growth managed stands may be achieved in several ways. Firstly, we can influence the species composition to target more valuable commercial species.

Secondly, through genetic manipulation we can increase tree size, fibre strength and log quality (Reed, 1988). Thirdly, gains can also be expected from enhanced tree form and structure, increased photosynthetic efficiency, and improved wood formation in the cellular wall in a manner which will contribute to strength and specific gravity. Reed (1988) stated that "these accomplishments will result in more profitable grades of lumber, higher lumber recovery per m^3 of logs sawn, larger lumber sizes, and an increase in average sales realization well in excess of 25 percent."

In addition, Reed (1988) concluded that the quality and grade of residual chips sold to the pulp mills would also be higher.

Silviculturally, only pruning will significantly increase the quality of stemwood by creating stronger knot-free wood. In second growth plantations stem diameters will not approach the larger average diameter of the old growth presently being harvested. The juvenile wood cores within these smaller plantation trees will therefore make up a higher proportion of the total volume of the tree. Since the wood quality of juvenile wood is much less than nature wood, the higher proportion of juvenile or crown wood will significantly reduce overall lumber product quality in second growth stands.

Pruning, through the removal of part of the live crown, provides an immediate transition from the production of this lower quality crown formed wood to higher quality, stronger mature or stem wood. This increase in lumber value may range from 25-40% (Kellogg, 1988; Sterling Wood, 1988).

Where spacing and fertilization will grow larger trees and more merchantable volume in a shorter period of time than in an untreated stand, only pruning will improve the value of second growth wood. Genetic selection and improvement may solve in part the juvenile core problem through improved natural pruning or selection for smaller branches (to minimize lumber degrade from larger knots) but for now artificial pruning is the most promising silviculture option for increasing wood and product value in second growth stands.

APPENDIX 2

SENSITIVITY ANALYSIS

SENSITIVITY ANALYSIS

Sensitivity analysis is a useful tool in tackling problems created by the existence of uncertainty pertaining to particular parameters incorporated into an investment analysis. The two parameters of concern in this analysis are the social discount rate and the aggregate coastal and aggregate interior site index values for good and medium sites.

It is evident from the analysis that Backlog reforestation is more sensitive to site productivity and, to a lesser extent, discount rates. GDP was the most sensitive of the economic indicators to discount rates and site productivity (demonstrates the largest variation). For GDP, revenue/cost ratios varied from 1.7 with a lower site index - high discount rate, to 12.6 for a higher site index -low discount rate combination.

Tables 2-1(1-3) and 2-2(1-3) represent a matrix of present value revenue/cost ratios for GDP, total government revenue and direct government revenue for a range of discount rates (3-5%) and site indices ranging from 15-22 m in the interior and 25-35 m on the coast. In terms of revenue/cost ratios the impact of silviculture investment on B.C.'s GDP and total revenue remains greater than one over the entire range of parameter values.

Tables 2-1(1-6), demonstrate a pattern for backlog reforestation and conifer release different from the other incremental activities. As site productivity increased the R/C ratios for all economic indicators increased accordingly. With the other incremental activities, however, with increasing site productivity the R/C ratios increased and peaked at an approximate site index of 20 m at BH50YRS.

For Tables 2-2(1-6), for all silvicultural treatments on the coast, the R/C ratios for all three economic indicators increased or increased and levelled off with increasing site productivity.

For coast and interior the revenue/cost ratios for all three economic indicators for all silvicultural treatments decreased as discount rates increased from 3 - 5 %.

TABLE 2-1-1: SENSITIVITY ANALYSIS OF THE REVENUE/COST RATIOS OF B.C. GDP SITE INDEX AND DISCOUNT RATE PARAMETERS

DISCOUNT RATE %	ACTIVITY	INTERIOR AVERAGE MANAGED STAND SITE INDICES FOR GOOD AND MEDIUM SITES			
		SITE INDEX = 15 m	SITE INDEX = 18 m	SITE INDEX = 20 m	SITE INDEX = 22 m
		R/C RATIO	R/C RATIO	R/C RATIO	R/C RATIO
3	BACKLOG REFORESTATION	2.9	6.2	8.4	11.1
	CONIFER RELEASE	4.1	8.8	11.9	15.8
	SPACING (NAT)	4.8	12.1	21.8	13.6
	SPACING/FERT (NAT)	5.8	11.5	19.2	12.8
	SPACING & FERT (PLANT)	13.2	25.3	30.0	24.2
	SPACING FERT & PRUNING (NAT)	3.6	7.0	11.7	7.8
	SPACING FERT & PRUNING (PLANT)	7.1	13.6	16.1	13.0
4	BACKLOG REFORESTATION	2.3	5.0	6.7	8.9
	CONIFER RELEASE	3.5	7.6	10.3	13.6
	SPACING (NAT)	4.5	11.4	20.6	12.9
	SPACING/FERT (NAT)	5.5	10.9	18.1	12.0
	SPACING & FERT (PLANT)	12.6	24.1	28.5	23.0
	SPACING FERT & PRUNING (NAT)	3.4	6.8	11.3	7.5
	SPACING FERT & PRUNING (PLANT)	6.8	13.1	15.5	12.5
5	BACKLOG REFORESTATION	1.9	4.1	5.6	7.4
	CONIFER RELEASE	3.1	6.7	9.0	11.9
	SPACING (NAT)	4.3	10.8	19.4	12.2
	SPACING/FERT (NAT)	5.2	10.3	17.1	11.4
	SPACING & FERT (PLANT)	12.0	23.0	27.2	22.0
	SPACING FERT & PRUNING (NAT)	3.3	6.5	10.8	7.2
	SPACING FERT & PRUNING (PLANT)	6.6	12.6	14.9	12.1

TABLE 2-2-1: SENSITIVITY ANALYSIS OF THE REVENUE/COST RATIOS OF B.C. GDP SITE INDEX AND DISCOUNT RATE PARAMETERS

DISCOUNT RATE %	ACTIVITY	COASTAL AVERAGE MANAGED STAND SITE INDICES FOR GOOD AND MEDIUM SITES			
		SITE INDEX = 25 m	SITE INDEX = 30 m	SITE INDEX = 33 m	SITE INDEX = 35 m
		R/C RATIO	R/C RATIO	R/C RATIO	R/C RATIO
3	BACKLOG REFORESTATION	2.4	7.0	8.8	12.6
	CONIFER RELEASE	2.5	7.4	9.4	13.3
	SPACING (NAT)	12.5	27.3	31.3	36.8
	SPACING/FERT (NAT)	11.8	23.5	26.7	30.9
	SPACING & FERT (PLANT)	7.4	20.4	23.1	23.1
	SPACING FERT & PRUNING (NAT)	7.0	13.9	15.8	18.3
	SPACING FERT & PRUNING (PLANT)	5.1	14.1	16.0	16.0
4	BACKLOG REFORESTATION	2.0	5.8	7.4	10.5
	CONIFER RELEASE	2.2	6.5	8.2	11.7
	SPACING (NAT)	11.8	25.7	29.5	34.7
	SPACING/FERT (NAT)	11.2	22.1	25.1	29.2
	SPACING & FERT (PLANT)	7.0	19.4	22.0	22.0
	SPACING FERT & PRUNING (NAT)	6.7	13.3	15.1	17.6
	SPACING FERT & PRUNING (PLANT)	4.9	13.6	15.3	15.3
5	BACKLOG REFORESTATION	1.7	5.0	6.3	9.0
	CONIFER RELEASE	2.0	5.8	7.3	10.4
	SPACING (NAT)	11.1	24.3	27.9	32.8
	SPACING/FERT (NAT)	10.6	20.9	23.7	27.5
	SPACING & FERT (PLANT)	6.7	18.5	20.9	20.9
	SPACING FERT & PRUNING (NAT)	6.5	12.8	14.5	16.8
	SPACING FERT & PRUNING (PLANT)	4.7	13.0	14.7	14.7

TABLE 2-1-3: SENSITIVITY ANALYSIS OF THE REVENUE/COST RATIOS OF TOTAL GOVERNMENT REVENUE TO SITE INDEX AND DISCOUNT RATE PARAMETERS

DISCOUNT RATE %	ACTIVITY	INTERIOR AVERAGE MANAGED STAND SITE INDICES FOR GOOD AND MEDIUM SITES			
		SITE INDEX = 15 m	SITE INDEX = 18 m	SITE INDEX = 20 m	SITE INDEX = 22 m
		R/C RATIO	R/C RATIO	R/C RATIO	R/C RATIO
3	BACKLOG REFORESTATION	0.6	1.3	1.7	2.3
	CONIFER RELEASE	0.8	1.7	2.4	3.1
	SPACING (NAT)	1.0	2.4	4.3	2.7
	SPACING/FERT (NAT)	1.2	2.3	3.8	2.5
	SPACING & FERT (PLANT)	2.6	5.0	5.9	4.8
	SPACING FERT & PRUNING (NAT)	0.7	1.4	2.3	1.5
	SPACING FERT & PRUNING (PLANT)	1.4	2.7	3.2	2.6
4	BACKLOG REFORESTATION	0.5	1.0	1.4	1.8
	CONIFER RELEASE	0.7	1.5	2.0	2.7
	SPACING (NAT)	0.9	2.3	4.1	2.6
	SPACING/FERT (NAT)	1.1	2.2	3.6	2.4
	SPACING & FERT (PLANT)	2.5	4.8	5.7	4.6
	SPACING FERT & PRUNING (NAT)	0.7	1.3	2.2	1.5
	SPACING FERT & PRUNING (PLANT)	1.4	2.6	3.1	2.5
5	BACKLOG REFORESTATION	0.4	0.9	1.2	1.5
	CONIFER RELEASE	0.6	1.3	1.8	2.4
	SPACING (NAT)	0.8	2.1	3.9	2.4
	SPACING/FERT (NAT)	1.0	2.0	3.4	2.3
	SPACING & FERT (PLANT)	2.4	4.6	5.4	4.4
	SPACING FERT & PRUNING (NAT)	0.7	1.3	2.1	1.4
	SPACING FERT & PRUNING (PLANT)	1.3	2.5	3.0	2.5

TABLE 2-2-3: SENSITIVITY ANALYSIS OF THE REVENUE/COST RATIOS OF TOTAL GOVERNMENT REVENUE TO SITE INDEX AND DISCOUNT RATE PARAMETERS

DISCOUNT RATE %	ACTIVITY	COASTAL AVERAGE MANAGED STAND SITE INDICES FOR GOOD AND MEDIUM SITES			
		SITE INDEX = 25 m	SITE INDEX = 30 m	SITE INDEX = 33 m	SITE INDEX = 35 m
		R/C RATIO	R/C RATIO	R/C RATIO	R/C RATIO
3	BACKLOG REFORESTATION	0.5	1.6	2.0	2.8
	CONIFER RELEASE	0.6	1.6	2.0	2.9
	SPACING (NAT)	2.7	6.0	6.9	8.1
	SPACING/FERT (NAT)	2.6	5.1	5.8	6.8
	SPACING & FERT (PLANT)	1.6	4.5	5.0	5.0
	SPACING FERT & PRUNING (NAT)	1.5	3.0	3.5	4.0
	SPACING FERT & PRUNING (PLANT)	1.1	3.1	3.5	3.5
4	BACKLOG REFORESTATION	0.5	1.3	1.7	2.4
	CONIFER RELEASE	0.5	1.4	1.8	2.6
	SPACING (NAT)	2.6	5.6	6.5	7.6
	SPACING/FERT (NAT)	2.5	4.8	5.5	6.4
	SPACING & FERT (PLANT)	1.5	4.2	4.8	4.8
	SPACING FERT & PRUNING (NAT)	1.5	2.9	3.3	3.8
	SPACING FERT & PRUNING (PLANT)	1.1	3.0	3.4	3.4
5	BACKLOG REFORESTATION	0.4	1.1	1.5	2.1
	CONIFER RELEASE	0.4	1.3	1.6	2.3
	SPACING (NAT)	2.4	5.3	6.1	7.2
	SPACING/FERT (NAT)	2.3	4.6	5.2	6.0
	SPACING & FERT (PLANT)	1.5	4.0	4.6	4.6
	SPACING FERT & PRUNING (NAT)	1.4	2.8	3.2	3.7
	SPACING FERT & PRUNING (PLANT)	1.0	2.8	3.2	3.2

TABLE 2-1-2: SENSITIVITY ANALYSIS OF REVENUE/COST RATIOS OF DIRECT GOVERNMENT REVENUE TO SITE INDEX AND DISCOUNT RATE PARAMETERS

DISCOUNT RATE %	ACTIVITY	INTERIOR AVERAGE MANAGED STAND SITE INDICES FOR GOOD AND MEDIUM SITES			
		SITE INDEX = 15 m	SITE INDEX = 18 m	SITE INDEX = 20 m	SITE INDEX = 22 m
		R/C RATIO	R/C RATIO	R/C RATIO	R/C RATIO
3	BACKLOG REFORESTATION	0.3	0.6	0.7	1.0
	CONIFER RELEASE	0.4	0.8	1.1	1.4
	SPACING (NAT)	0.4	1.1	1.9	1.2
	SPACING/FERT (NAT)	0.5	1.0	1.7	1.1
	SPACING & FERT (PLANT)	1.2	2.2	2.7	2.1
	SPACING FERT & PRUNING (NAT)	0.3	0.6	1.0	0.7
	SPACING FERT & PRUNING (PLANT)	0.6	1.2	1.4	1.2
4	BACKLOG REFORESTATION	0.2	0.4	0.6	0.8
	CONIFER RELEASE	0.3	0.7	0.9	1.2
	SPACING (NAT)	0.4	1.0	1.8	1.1
	SPACING/FERT (NAT)	0.5	1.0	1.6	1.1
	SPACING & FERT (PLANT)	1.1	2.1	2.5	2.0
	SPACING FERT & PRUNING (NAT)	0.3	0.6	1.0	0.7
	SPACING FERT & PRUNING (PLANT)	0.6	1.2	1.4	1.1
5	BACKLOG REFORESTATION	0.2	0.4	0.5	0.7
	CONIFER RELEASE	0.3	0.6	0.8	1.1
	SPACING (NAT)	0.4	1.0	1.7	1.1
	SPACING/FERT (NAT)	0.5	0.9	1.5	1.0
	SPACING & FERT (PLANT)	1.1	2.0	2.4	1.9
	SPACING FERT & PRUNING (NAT)	0.3	0.6	1.0	0.6
	SPACING FERT & PRUNING (PLANT)	0.6	1.1	1.3	1.1

TABLE 2-2-2: SENSITIVITY ANALYSIS OF REVENUE/COST RATIOS OF DIRECT GOVERNMENT REVENUE TO SITE INDEX AND DISCOUNT RATE PARAMETERS

DISCOUNT RATE %	ACTIVITY	COASTAL AVERAGE MANAGED STAND SITE INDICES FOR GOOD AND MEDIUM SITES			
		SITE INDEX = 25 m	SITE INDEX = 30 m	SITE INDEX = 33 m	SITE INDEX = 35 m
		R/C RATIO	R/C RATIO	R/C RATIO	R/C RATIO
3	BACKLOG REFORESTATION	0.3	0.8	1.0	1.4
	CONIFER RELEASE	0.3	0.8	1.0	1.5
	SPACING (NAT)	1.4	3.0	3.4	4.0
	SPACING/FERT (NAT)	1.3	2.6	2.9	3.4
	SPACING & FERT (PLANT)	1.3	2.2	2.5	2.5
	SPACING FERT & PRUNING (NAT)	0.8	1.5	1.7	2.0
	SP..CING FERT & PRUNING (PLANT)	0.6	1.5	1.7	1.7
4	BACKLOG REFORESTATION	0.2	0.6	0.8	1.1
	CONIFER RELEASE	0.2	0.7	0.9	1.3
	SPACING (NAT)	1.3	2.8	3.2	3.8
	SPACING/FERT (NAT)	1.2	2.4	2.7	3.2
	SPACING & FERT (PLANT)	0.8	2.1	2.4	2.4
	SPACING FERT & PRUNING (NAT)	0.7	1.5	1.7	1.9
	SPACING FERT & PRUNING (PLANT)	0.5	1.5	1.7	1.7
5	BACKLOG REFORESTATION	0.2	0.5	0.7	1.0
	CONIFER RELEASE	0.2	0.6	0.8	1.1
	SPACING (NAT)	1.2	2.7	3.0	3.6
	SPACING/FERT (NAT)	1.2	2.3	2.6	3.0
	SPACING & FERT (PLANT)	0.7	2.0	2.3	2.3
	SPACING FERT & PRUNING (NAT)	0.7	1.4	1.6	1.8
	SPACING FERT & PRUNING (PLANT)	0.5	1.4	1.6	1.6

TABLE 2-1-4: SENSITIVITY ANALYSIS OF THE NPV OF GDP RETURN FROM FRDA INVESTMENTS TO SITE INDEX AND DISCOUNT RATE PARAMETERS

DISCOUNT RATE %	ACTIVITY	INTERIOR AVERAGE MANAGED STAND SITE INDICES FOR GOOD AND MEDIUM SITES			
		SITE INDEX = 15 m	SITE INDEX = 18 m	SITE INDEX = 20 m	SITE INDEX = 22 m
		(000's of $)			
3	BACKLOG REFORESTATION	277,370.4	759,652.0	1,077,678.4	1,472,590.1
	INTENSIVE MANAGEMENT	110,403.5	249,619.7	67,915.4	290,737.7
	TOTAL	387,773.9	1,009,271.7	1,507,542.4	1,763,327.8
4	BACKLOG REFORESTATION	185,787.3	557,394.1	802,439.1	1,106,725.8
	INTENSIVE MANAGEMENT	102,019.5	232,460.2	401,863.0	270,018.5
	TOTAL	287,806.8	789,854.3	1,204,302.1	1,376,744.3
5	BACKLOG REFORESTATION	126,214.1	424,044.1	620,439.2	864,314.5
	INTENSIVE MANAGEMENT	94,546.0	217,183.5	376,804.1	251,839.5
	TOTAL	220,760.1	641,227.6	997,243.4	1,116,153.9

TABLE 2-2-4: SENSITIVITY ANALYSIS OF THE NPV OF GDP RETURN FROM FRDA INVESTMENTS TO SITE INDEX AND DISCOUNT RATE PARAMETERS

DISCOUNT RATE %	ACTIVITY	COASTAL AVERAGE MANAGED STAND SITE INDICES FOR GOOD AND MEDIUM SITES			
		SITE INDEX = 25 m	SITE INDEX = 30 m	SITE INDEX = 33 m	SITE INDEX = 35 m
		(000's of $)			
3	BACKLOG REFORESTATION	(11,787.1)	94,977.2	125,082.9	184,660.7
	INTENSIVE MANAGEMENT	5,268.7	472,022.6	540,330.9	634,431.7
	TOTAL	(6,518.4)	566,999.8	665,412.9	819.092.4
4	BACKLOG REFORESTATION	(11,988.8)	73,831.4	98,031.2	145,921.5
	INTENSIVE MANAGEMENT	3,728.5	443,208.8	507,444.0	595,834.7
	TOTAL	(8,260.3)	517,040.2	604,574.2	741,756,2
5	BACKLOG REFORESTATION	10,416.2	58,656.1	78,581.3	118,012.2
	INTENSIVE MANAGEMENT	196,246.4	416,929.6	477,469.9	560,702.0
	TOTAL	206,662.6	475,585.7	556,051.2	678,714.2

NOTE: ( ) indicates negative value

TABLE 2-1-6: SENSITIVITY ANALYSIS OF THE NPV OF TOTAL GOVERNMENT REVENUE RETURN FROM FRDA INVESTMENTS TO SITE INDEX AND DISCOUNT RATE PARAMETERS

DISCOUNT RATE %	ACTIVITY	INTERIOR AVERAGE MANAGED STAND SITE INDICES FOR GOOD AND MEDIUM SITES			
		SITE INDEX = 15 m	SITE INDEX = 18 m	SITE INDEX = 20 m	SITE INDEX = 22 m
		(000's of $)			
3	BACKLOG REFORESTATION	(59,151.8)	39,327.6	104,266.9	184,905.9
	INTENSIVE MANAGEMENT	2,604.6	30,203.9	65,936.8	38,355.4
	TOTAL	(56,547.2)	69,531.5	170,203.8	223,261.3
4	BACKLOG REFORESTATION	(72,863.2)	3,753.7	54,276.4	117,013.4
	INTENSIVE MANAGEMENT	957.2	26,816.8	60,400.5	34,262.6
	TOTAL	(71,906.0)	30,570.5	114,676.8	151,276.0
5	BACKLOG REFORESTATION	(80,567.6)	(18,571.4)	22,310.2	73,075.2
	INTENSIVE MANAGEMENT	(510.1)	23,802.5	55,446.9	30,673.1
	TOTAL	(81,077.7)	5,231.1	77,757.1	103,748.2

NOTE: ( ) indicates negative value

TABLE 2-2-5: SENSITIVITY ANALYSIS OF THE NPV OF TOTAL GOVERNMENT REVENUE RETURN FROM FRDA INVESTMENTS TO SITE INDEX AND DISCOUNT RATE PARAMETERS

DISCOUNT RATE %	ACTIVITY	COASTAL AVERAGE MANAGED STAND SITE INDICES FOR GOOD AND MEDIUM SITES			
		SITE INDEX = 25 m	SITE INDEX = 30 m	SITE INDEX = 33 m	SITE INDEX = 35 m
		(000's of $)			
3	BACKLOG REFORESTATION	(7,366.0)	9,065.2	15,852.0	29,282.7
	INTENSIVE MANAGEMENT	4782.5	50,825.6	34,584.7	6,225.9
	TOTAL	24,763.8	95,606.9	117,343.8	151,370.2
4	BACKLOG REFORESTATION	(8,368.1)	4,968.0	10,476.4	21,377.2
	INTENSIVE MANAGEMENT	29,031.1	80,244.0	94,302.9	113,648.6
	TOTAL	20,663.0	85,212.0	104,779.3	135,025.8
5	BACKLOG REFORESTATION	(8,968.4)	2,117.5	6,696.5	15,758.1
	INTENSIVE MANAGEMENT	26,200.8	64,500.9	87,751.1	105,967.8
	TOTAL	17,232.4	76,618.4	94,447.6	121,725.9

NOTE: ( ) indicates negative value

TABLE 2-1-5: SENSITIVITY ANALYSIS OF THE NPV OF DIRECT GOVERNMENT REVENUE RETURN FROM FRDA INVESTMENTS TO SITE INDEX AND DISCOUNT RATE PARAMETERS

DISCOUNT RATE %	ACTIVITY	INTERIOR AVERAGE MANAGED STAND SITE INDICES FOR GOOD AND MEDIUM SITES			
		SITE INDEX = 15 m	SITE INDEX = 18 m	SITE INDEX = 20 m	SITE INDEX = 22 m
		(000's of $)			
3	BACKLOG REFORESTATION	(108,051.8)	(65,342.5)	(37,179.1)	(2,207.0)
	INTENSIVE MANAGEMENT	12,143.7	184.8	16,146.6	3,826.1
	TOTAL	(120,195.5)	(65,157.7)	(21,032.5)	1,619.1
4	BACKLOG REFORESTATION	(111,187.4)	(78,279.1)	(56,578.7)	(29,632.1)
	INTENSIVE MANAGEMENT	(12,869.5)	1,318.1	13,683.7	2,008.0
	TOTAL	(124,056.9	(79,597.2)	(42,895.1)	(27,624.2)
5	BACKLOG REFORESTATION	(111,800.9)	(85,426.0)	(68,033.9)	(46,437.1)
	INTENSIVE MANAGEMENT	(13,515.0)	(2,564.6)	11,480.9	279.9
	TOTAL	(125,315.9)	(88,080.6)	(56,553.1)	(46,022.7)

NOTE: ( ) indicates negative value

TABLE 2-2-6: SENSITIVITY ANALYSIS OF THE NPV OF DIRECT GOVERNMENT REVENUE RETURN FROM FRDA INVESTMENTS TO SITE INDEX AND DISCOUNT RATE PARAMETERS

DISCOUNT RATE %	ACTIVITY	COASTAL AVERAGE MANAGED STAND SITE INDICES FOR GOOD AND MEDIUM SITES			
		SITE INDEX = 25 m	SITE INDEX = 30 m	SITE INDEX = 33 m	SITE INDEX = 35 m
		(000's of $)			
3	BACKLOG REFORESTATION	22,089.5	(3,829.5)	(542.7)	5,961.7
	INTENSIVE MANAGEMENT	223,414.4	32,410.5	39,868.0	50,141.6
	TOTAL	245,503.9	28,581.0	39,325.3	56,103.3
4	BACKLOG REFORESTATION	15,242.2	(5,592.3)	(2,950.3)	2,278.2
	INTENSIVE MANAGEMENT	209,216.9	29,274.7	36,287.6	45,937.6
	TOTAL	224,459.1	23,682.4	33,337.3	48,215.8
5	BACKLOG REFORESTATION	(12,004.6)	(6,738.0)	(4,562.7)	(257.8)
	INTENSIVE MANAGEMENT	2,322.1	26,415.3	33,024.8	42,111.7
	TOTAL	(9,682.5)	19,677.3	28,462.1	41,853.9

NOTE: ( ) indicates negative value

APPENDIX 3

ECONOMICS OF SILVICULTURE

1. TITLE: ECONOMICS OF SILVICULTURE

AGENCY: B.C. FOREST SERVICE

CONTRACTOR: FOREST ECONOMICS AND POLICY ANALYSIS RESEARCH UNIT (FEPA)
SUB-CONTRACTOR: ENVIRONMENTAL & SOCIAL SCIENCES ASSOCIATION (ESSA)

DESCRIPTION:

The objective is to develop a comprehensive modeling system for the use of planning and project evaluation. The modeling methodology will provide linkages between broad strategic options and operational planning at the district level. The model will provide multiple rotation, regional timber supply and inventory projections, costs of harvesting, and other economic data such as employment, industrial development and government revenues.

This evaluation of silvicultural investments is conducted in the context of general forest management strategies, including protection. The general aim of this model is to facilitate analysis of policy decisions.

DOLLARS INVESTED: Approx. $50,000.00 to date.

WHEN AVAILABLE: Spring 1989.

2. TITLE: ARTICULATION OF PREFERENCES OVER OBJECTIVES FOR EVALUATING SILVICULTURAL INVESTMENT OPTIONS

AGENCY: B.C. FOREST SERVICE

CONTRACTOR: FOREST ECONOMICS AND POLICY ANALYSIS RESEARCH UNIT (FEPA)

DESCRIPTION:

The objective is the identification and measurement of the different dimensions of benefits and costs used to evaluate alternative silvicultural investments, taking into account social preferences for risk-taking and time. Alternative methods and indicies will be tested using panels of decision-makers and stake-holders at various levels of the decision-making hierarchy.

The output of this project will consist of several manuals through which the methodology is defined and therefore can be repeated. The manual will also include a guide for using trade-off information for silvicultural decision models. After conducting a case study, FEPA plans to issue a report including policy recommendations based on findings.

DOLLARS INVESTED: $35,000.00 in fiscal year 88/89.

WHEN AVAILABLE: Winter, 1989/90.

3. TITLE: FRDA - BIOLOGICAL RESPONSE TO SILVICULTURAL TREATMENTS

AGENCY: B.C. FOREST SERVICE (COST-SHARED FRDA)

CONTRACTOR: STEPHEN SMITH & ASSOCIATES FORESTRY CONSULTANTS

DESCRIPTION:

This study will provide detailed estimates by major species type of changes in merchantable volumes, stocking, diameter and other relevant stand variables resulting from specified silvicultural treatments. Also the degree of certainty regarding these estimates will be identified and a range of possible values for the variables will be specified where possible.

DOLLARS INVESTED: $45,000

WHEN AVAILABLE: March, 1989.

4. TITLE: FRDA - EMPLOYMENT GENERATION

AGENCY: B.C. FOREST SERVICE (COST-SHARED UNDER FRDA)

CONTRACTOR: DELOITTE, HASKINS & SELLS

DESCRIPTION:

This study will survey silviculture contractors and their employees in order to determine the amount and type of employment generated by different silvicultural activities. This study will also focus on the breakdown of contract costs into labour payments, material and supplies and other categories.

DOLLARS INVESTED: $45,000

WHEN AVAILABLE: March, 1989.

5. TITLE: FRDA - DELIVERED WOOD COSTS

AGENCY: B.C. FOREST SERVICE (COST-SHARED UNDER FRDA)

CONTRACTOR: STIRLING WOOD GROUP

DESCRIPTION:

This study will investigate the relationship between delivered wood costs and various factors including proximity to the mill, terrain, accessibility, etc.

DOLLARS INVESTED: $45,000

WHEN AVAILABLE: March, 1989.

6. TITLE: FRDA - OVERALL EVALUATION

AGENCY: B.C. FOREST SERVICE (COST-SHARED UNDER FRDA)

CONTRACTOR: TO BE AWARDED IN FY 89/90

DESCRIPTION:

This project, to be conducted in the final year of FRDA, will build on and consolidate all previous studies under the FRDA evaluation program. The project will involve overall analysis of the benefits of the entire Agreement. As far as possible the benefits will be presented in a form which is comparable to other government programs. This will mean a focus on cost-benefit techniques, recognizing social benefits.

DOLLARS INVESTED: N/A

WHEN AVAILABLE: March, 1990.

7. TITLE: FRDA - AN ANALYSIS OF CHANGES IN TIMBER VALUES DUE TO SILVICULTURE TREATMENTS UNDER THE CANADA-BRITISH COLUMBIA FOREST RESOURCE DEVELOPMENT AGREEMENT

AGENCY: B.C. FOREST SERVICE (cost-shared under FRDA)

CONTRACTOR: STERLING WOOD GROUP INC.

DESCRIPTION:

The objective of the study was to develop tools that could be used to determine the changes in value of tree stems that may result from changes in tree size, particularly in diameter, brought about through various treatments.

DOLLARS INVESTED: $38,960

WHEN AVAILABLE: Published as FRDA report #041 July/88

8. TITLE: FRDA - THE SOCIAL DISCOUNT RATE FOR SILVICULTURAL INVESTMENTS

AGENCY: B.C. FOREST SERVICE (cost-shared under FRDA)

CONTRACTOR: Dr. Terry Heaps - Dept. of Economics
Simon Fraser University

(8 cont'd)

DESCRIPTION:

This study will propose an appropriate rate for equating silvicultural returns which vary widely in timing. This study will include an extensive literature review including a documentation of the justification for and the specific rates used for forest investment analysis in other countries. New approaches to establishing a discount rate will be examined.

DOLLARS INVESTED: $6,850

WHEN AVAILABLE: (draft rec'd) final March 1989

9. TITLE: FORCYTE-11

AGENCY: UNIVERSITY OF BRITISH COLUMBIA

CONTRACTOR: DRS. J.P. KIMMINS AND D. HALEY
(FACULTY OF FORESTRY - UBC)

DESCRIPTION:

An earlier version of Forcyte (Forcyte-10) had a simplistic economics and energy benefit cost analysis package, but there is a need to redesign this economics package for use in Forcyte-11. This modification would enhance its usefulness as a tool of forestry education, extension, research, and management with respect to the stand level economics of silviculture.

DOLLARS INVESTED: Proposal - $23,500.00

WHEN AVAILABLE: ?

10. TITLE: FOREST LEVEL SILVICULTURE IMPACT ANALYSIS: JOINT PROJECT

AGENCY: FORESTRY CANADA AND B.C. FOREST SERVICE

CONTRACTOR: AWARDED BY FORESTRY CANADA

DESCRIPTION:

The objective of the project is to develop analytical tools and methodologies to examine the impact of silviculture investment on value and volume on a forest-wide level. This will be done using existing models and also using delivered wood costs produced through currently used models. Having completed the model verification, a practical application will be tested using the Strathcona TSA as a prototype.

(10 cont'd)

DOLLARS INVESTED: **$20,000 PLUS STAFF TIME**

WHEN AVAILABLE: **Will have to conclude by Spring, 1990.**

11. **TITLE:** **SILVICULTURE DECISION SUPPORT SYSTEMS (SDSS)**

AGENCY: **FORESTRY CANADA & DEPARTMENT OF SUPPLY & SERVICES**

CONTRACTOR: **McDANIELS RESEARCH LIMITED**

DESCRIPTION:

The SDSS is described as, "an uncertainty model and evaluation framework for silviculture investment decisions". It is designed for use by field and planning foresters and economists who want to set priorities for silviculture activities. The model incorporates multiple objectives, uncertainties, and both the stand and forest level perspectives. It provides an ability to analyse hundreds of different options for hundreds of different treatment groups, or to analyze a few options for one treatment group.

The model is being developed in three phases with phase one nearing completion. Phase two consists of a case study in a TSA in the Vancouver forest region. Phase three will consist of implementation and expanding the models capability to the full area of the province.

DOLLARS INVESTED: N/A

WHEN AVAILABLE: Spring 1989.

12. **TITLE:** **DOUGLAS-FIR TASK FORCE**

AGENCY: **FORINTEK CANADA CORP.**

CONTRACTOR: **FORINTEK CANADA CORP.**

DESCRIPTION:

Major work has been done on second-growth Douglas-fir and how the material can be managed and handled for value. In particular, the report has included validating growth and yield models based on data collected from second-growth stands. The objective is also to be able to link growth and yield projections with bucking and sawmilling models and then relating that data to rating routines and, finally, a financial analysis. This will aid managers in choosing silvicultural treatments on Douglas-fir stands.

DOLLARS INVESTED: **Approx. $1.2 Million**

WHEN AVAILABLE: **1989.**

13. TITLE: LODGEPOLE PINE TASK FORCE END-PRODUCT VALUE RECOVERY

AGENCY: FORINTEK CANADA CORP.

CONTRACTOR: FORINTEK CANADA CORP.

DESCRIPTION:

This research will provide the most comprehensive assessment available for the future of lodgepole pine resource. The information will permit planning for its optimum utilization. In addition, it will provide a basis for developing silvicultural strategies which will maximize the recovery of end-product value.

DOLLARS INVESTED: Proposed: $2.022 Million
Invested: $687,000 (Forintek and Paprican)

WHEN AVAILABLE: 1992.

14. TITLE: ECONOMIC IMPACT MONITORING PROGRAM

AGENCY: B.C. FOREST SERVICE

CONTRACTOR: SHUSWAP COMMUNITY FUTURES COMMITTEE

DESCRIPTION:

The objective of this program is to produce a validated model which will clearly forecast the full economic and employment benefits which will accrue from sustained intensive forest management programs. This model will be an extremely valuable tool to forest managers and to public funding managers because it will provide a basis upon which to make priority funding decisions between public programs. The model will provide the vehicle to validate the forester's assertion regarding the economic and employment potential of IFM. Further, it will provide a sound basis for increased funding of IFM programs which will realize the benefits associated with the programs.

DOLLARS INVESTED: Proposed: $7.535 million

WHEN AVAILABLE: 1994

15. TITLE: COMPANY SPECIFIC ANALYSES

This report shows, on a broad basis, a benefit cost-analysis for silvicultural treatments. Of necessity, for such a report the same basis must be used across the Province. In the real world, this will not be the case. Companies will have their own specific analyses which will be dependent upon location, mill structure, market position, and expected future in the business. Specific decisions by different companies may well take a different approach and this should be recognized in a world where markets exist and free choice is given.

Queen's Printer for British Columbia©
Victoria

7680000097